ACTIVITY 13

CLIMATE AND THE GREENHOUSE EFFECT

This module is intended to help educators guide an experiment to demonstrate the greenhouse effect and to stimulate discussion among students on the effects of global climate changes upon the environment. While global warming may sound great ("endless summer"), thinking through the possible effects upon plants, sea levels, and the world's food supply may cause the students to better appreciate how complex a role the atmosphere plays in the way we live. This activity is related to the warm-ups called "Prediction" and "Tracking Air Quality." Related activities include "The Greenhouse Effect."

CRITICAL OBJECTIVES

- Recognize that relatively small changes to our environment can stimulate significant climate changes
- Understand that the "scientific method" is a process of testing hypotheses
- Appreciate that global climate changes will affect us far beyond simply warming the outdoor air temperatures

SKILLS

- Observing
- Forming hypotheses
- Predicting
- Graphing

GUEST PRESENTERS

Guest presenters could include chemists, ecologists, environmental scientists, EPA environmental protection specialists, meteorologists, or physicists.

BACKGROUND

Most of the electromagnetic energy (light) radiated from the sun that reaches the Earth passes through our atmosphere and is absorbed at the surface. Some of the incoming, or "incident," light waves are reflected away by clouds in the atmosphere or light-colored surface features such as large snow or ice fields. The energy that is absorbed is converted in part to heat energy that is re-radiated back into the atmosphere. Heat energy waves are not visible, and are generally in the infrared (long-wavelength) portion of the spectrum compared to visible light. Physical laws show that atmospheric constituents—notably water vapor and carbon dioxide gas—that are transparent to vis-

RELATED WARM-UP
A, E

REFER TO READING MATERIAL
"Greenhouse Effect"
"Air Pollution"

TARGET GRADE LEVEL
8th - 12th

DURATION
35 minutes (or two class periods with extensions)

VOCABULARY
Baseline
Carbon dioxide
Convection
Energy
Greenhouse effect
Hypothesis
Prediction
Scientific method
Temperature

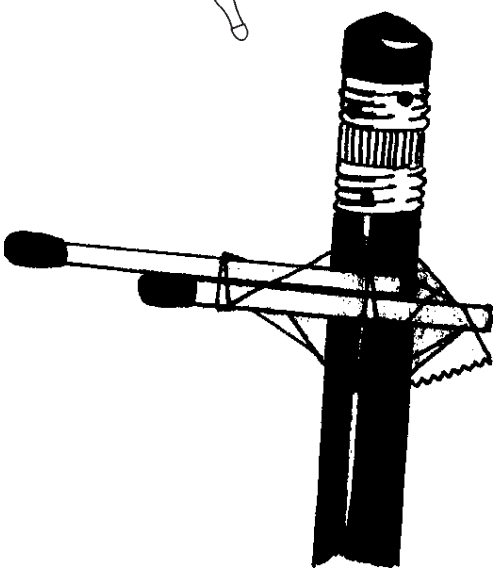
MATERIALS
A clean, dry, wide-mouth glass jar with a tight cap (such as a mayonnaise jar)
Thermometer capable of fitting into the jar (meat thermometer works well)
Heavy aluminum foil
Stop watch (or clock with a second hand)
Wooden kitchen matches
Graph paper
Colored pencils

ible light are not transparent to heat waves. Hence, re-radiated energy in the infrared portion of the spectrum is trapped within the atmosphere, keeping the surface temperature warm. This phenomenon is called the "greenhouse effect" because it is exactly the same principle that heats a greenhouse (or in a glass jar as in this experiment) where the glass performs the same function as the atmosphere. On the moon, for example, where there is no atmosphere, re-radiated energy is entirely lost to space. Thus, objects on the surface of the moon would feel hot if they were in direct sunlight while the side turned away from the direct rays of the sun would be as cold as space. Obviously, the Earth's atmosphere serves a function beyond providing air to breathe: the atmosphere mediates the extremes of energy received from the sun, and serves as an energy storehouse. (See reading materials on "The Greenhouse Effect" and "Air Pollution.")

WHAT TO DO

Before class begins

1. Make a number of match holders (see illustration) that will keep the burning match away from the thermometer.



When class begins

1. Students should be challenged throughout the activity to volunteer predictions of what will happen in each step of the experiment. Where appropriate, ask them to write down actual numbers that they expect to see during the experiments. They should then be encouraged to suggest reasons why their hypotheses were (or were not) substantiated by experiment. Finally, they should be encouraged to explain the real-world implications of the experiments in the glass jar.

2. Have the students create a graph with temperature along the vertical axis (50° to 200°F, in 5° increments) and time along the horizontal axis (0 minutes to 20 minutes). Tell the students to label each axis. Have them use a different colored pencil to enter data for each version of the experiment so they can compare data.

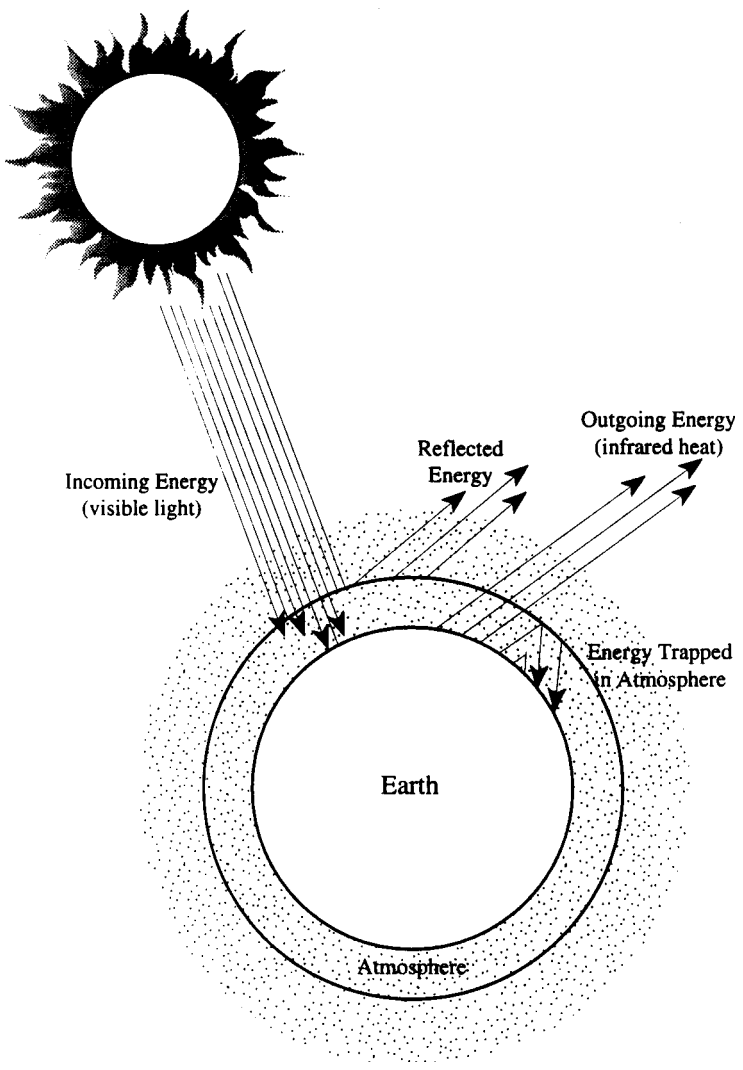
3. Select a student or group of students to perform the experiment. Have them wrap one half the jar's circumference with heavy aluminum foil, shiny side out, making sure that the foil extends the entire height of the jar. They can tape it in place if necessary.

4. Have them put the thermometer in the jar so that it can be read through the side of the jar that is not covered with foil. Leave the lid off for now.

5. Let them measure the air temperature in the room, making sure that the thermometer is not in direct sunlight or close to an electric light bulb. Have all students read and write down the temperature.

6. Have the experimenter(s) place the jar in a sunny window, or next to the spotlight. Caution that the thermometer should be completely shadowed by the aluminum foil (rotate the jar so that the foil faces the sun). Have each student write down the temperature. Have the students predict whether the temperature will be different from the first temperature, and by how many degrees, and make them give a hypothesis. If they think that the temperature will go up, ask them to explain the mechanism by which the heat is added to the jar. (The temperatures should not be appreciably different, because you are reading the room air temperature both times.) Ask the students to consider what temperature is really being measured. (It is really the temperature of the air within the jar.)

7. Have the experimenter(s) rotate the jar so that sunlight hits the clear side of the jar and the thermometer directly. Ask the students to predict what the temperature will now do. Get them to suggest reasons. The temperature should be much warmer, because the energy in the sunlight is directly warming the mercury in the thermometer as it converts from visible light energy to invisible heat energy. If anyone guesses the answer, challenge them to think of a way to test that theory. The next experiment will test the theory.



8. Rotate the jar again so that the thermometer is shadowed. Start the stopwatch. Call students' attention to how long it takes for the temperature to fall back to normal room temperature. It should fall fairly quickly because the increase was due only to the sunlight. The air within the jar was not warmed much because it is open to the room and any heated air escaped and was replaced by cold air through convection.

9. Cover the jar with the lid snugly, and repeat steps 6, 7, and 8. Have the students use a different colored pencil to record the temperature curve on their graph paper. Ask the students to predict whether the results will be the same, and why or why not. Even with the cover on, the repeat of 6 should not increase the temperature significantly because the sunlight is being reflected away from the jar. When the sunlight hits the clear part of the jar in the repeat of experiment 7, the temperature will go up just as quickly as before. However, when you turn the jar away in the repeat of 8, the temperature will fall much more slowly because of the greenhouse effect. Ask why the temperature fell more slowly than before? If heat was stored in the jar, what part of the system was probably the heat "bank"? The gases in the system, including water vapor.

10. Open the jar and drop in a lighted kitchen match attached to the match holder and quickly close the lid again.

When the oxygen is gone, the match will die out by itself in about ten seconds. Challenge the students to guess what the burning matches are doing in the closed system. The fire is combining the oxygen in the enclosed air with the carbon from the burning wood to produce carbon dioxide. Ask them what in the real world might create a similar situation in the atmosphere. Ask them why the match went out even though not all of the wooden match stick was burned up. Set the jar aside away from sunlight for a couple of minutes to let the heat created by the fire equilibrate. The match didn't give off much heat, but the temperature will likely go up about 5°F (3°C). Have the students read the thermometer (to get a temperature baseline). Repeat steps 7 and 8, asking the students to again predict what will happen and why. This time, emphasize that they should consider and speculate on whether the carbon dioxide in the jar will accelerate or retard the temperature rise and later fall. This time, the temperature will warm up much more quickly and will stay warm longer because of the greenhouse effect of the carbon dioxide.

TAKE NOTE! Be careful that the flame does not touch the thermometer or any plastic or cardboard casing around it.

11. Challenge the students to extrapolate the results of the experiments to the real world. The conclusion of these experiments should demonstrate that the greenhouse effect is real, that a colorless atmospheric gas (carbon dioxide) is a significant contributor to atmospheric warming.

SUGGESTED EXTENSIONS (OPTIONAL)

☼ Divide the class into three groups and have Group One conduct and record the experiments with the jar open to the air; Group Two should conduct the experiments with the jar sealed, and Group Three with the jar sealed after the matches are burned in it. (Don't forget to pre-

pare the match holders before class). If results from measurements of more than one thermometer are to be compared, be sure to calibrate the thermometers with each other first to cancel out analytical errors.

- Divide the class into three groups and have each group conduct the identical experiments. Compare their results. Discuss why the values were different? Discuss calibration of the thermometers, "experimental errors," and different conditions.

- Have the students plant a tree. Explain that they can make a small dent in the carbon dioxide surplus by planting trees. Have the students contact a local nursery to see if the owners will donate some tree seedlings to help combat climate change.

SUGGESTED MODIFICATIONS

- For grades 10 through 12, divide the class into two groups. Have one group represent the position of the United States and our citizens. The other group should represent a poor country that relies upon subsistence agriculture, fishing, and the sale of its forests for lumber to the United States. The groups should work separately. Each group should make a list of the benefits it (the represented country) would receive if global warming was halted. Each group should list the things it can do within its own borders to help stop global warming. Each group then should list the "costs" it would be required to bear to help stop global warming. Have students discuss whether the benefits to both groups are the same. Can both countries contribute equally to slow down or stop global warming? Are the costs to both groups the same?

- Have students in higher grades research and present oral reports to the class to answer the following questions:
  How can greenhouse gases be controlled, and is the greenhouse effect reversible?
  If temperatures are warming, what are the consequences to humans from melting polar icecaps?
  If the greenhouse effect is raising global temperatures to an appre ciable degree, what will happen to the world's food supply in the next century?

SUGGESTED READING

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